Canadian SPACE GAZETTE

November 2005

Terrapin Station:

An Alternative Approach To Space Exploration

Charles Eric LaForest
Waterloo Space Society

A terrapin is a soft-water aquatic turtle. Like a turtle, the model of space exploration proposed here is slow and long-lived.

"Terrapin Station"[1] is a song by The Grateful Dead which contains a couple of verses with astronomical mentions, and could be taken as a reference to a space station at L5:

Counting stars by candlelight
all are dim but one is bright:
the spiral light of Venus
rising first and shining best,
From the northwest corner
of a brand-new crescent moon
crickets and cicadas sing
a rare and different tune

Terrapin Station
in the shadow of the moon
Terrapin Station
and I know we'll be there soon

(Words by Robert Hunter. Music by Jerry Garcia. Copyright Ice Nine Publishing.)

Current plans for manned Mars missions, or indeed any other manned missions, involve a large rocket, fast travel, and a supply of consumables. A finite supply of power, air, food, and water limits possible travel time, which must then follow a high-energy trajectory, and thus requires a large, high-thrust, low-efficiency (low specific impulse) means of propulsion. These requirements increase proportionally with the distance traveled.

I propose an alternative approach to exploring space. It involves smaller rockets, a large space station, slow travel, and a renewable life-support system. A solar-powered, self-sustaining source of air, food, and water makes longer, lower-energy trips possible, and thus makes practical the use of small, low-thrust, high-efficiency means of propulsion. These requirements remain constant relative to the distance traveled, with the exception of propellant.

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President's Message

Welcome to the fall issue of the Canadian Space Gazette. As I am able to insert this section at the last moment, I can add a short summary of the breaking news since the last issue.

By far the most significant, from the perspective of human space exploration and development, was the second manned launch by the Chinese. While some may question their motives, or doubt their long-term viability, no-one can belittle their achievements. Since mid-2003 they are 2:1 up on the USA! All those who think friendly competition is a good thing should be cheering them on.

The third tourist to the ISS, Greg Olsen, was successfully launched and returned by the Russians, and Daisuke Enomoto has been confirmed as next in the queue. While business is going well at the top of the space tourism pyramid, the X-Prize Cup saw 20,000 people gather in the New Mexico desert to enjoy the other end of the space tourism cost curve.

The planned "Rocket Racing League" will be very exciting, so stay tuned.

In the pursuit of scientific knowledge, ESA's Venus Express was launched successfully this evening, and will be in orbit about Venus in less than 6 months.

The University of Toronto also got some hardware into space, with a number of deployer systems ejecting three nanosats, each weighing only a couple of kilograms, out the side of the small SSETI Express satellite.

You may have seen the CSS press release regarding the McLaughlin Planetarium. The Royal Ontario Museum announced earlier this week that is has canceled plans for the building's demolition and the subsequent condominium development, however we are still a long way from having an operational planetarium. Strategy will be discussed at the Space Summit, so stay tuned.

Many of you may be reading this at the Canadian Space Summit, and I expect there will be many new and interesting projects coming out of this year's event. For those of you who couldn't make it to the Summit, please remember that the CSS AGM is on January 16th. Visit www.css.ca to secure your society membership, and join the grand adventure.

Ad Astra,

Daniel

The **Canadian Space Society** is a grass-roots space advocacy group, a unique combination of amateur and professional interests pursuing the human exploration and development of the Solar System. With some of Canada's top aerospace experts and engineers on board, the CSS is made up of people of all backgrounds and interests, including teachers, environmentalists, writers, and marketers.

Our principal objective is to sponsor and promote the involvement of Canadians in the development of Space. This objective will allow us to grow in cooperation, rather than in competition, with other space-development organizations (such as the National Space Society and the British Interplanetary Society), while meeting a real need for an effective Canadian space-development advocacy group.

In order to help carry out our principal objective, we pursue the following additional goals:

- to provide meeting and working places to Society members for the purposes of discussion, presentation and development of Space and Space-related technologies;
- to sponsor, promote and engage in activities designed to promote increased knowledge of Space and Space-related technologies among Society members, and the general public;
- to pursue the manufacture, printing, publication, and distribution of Space-related materials and products.

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Please have a look at our member organizations.

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TERRAPIN STATION
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It begins on Earth. The first step is to create a sustainable closed life-support system. There has already been significant past work done in Russia[2] and currently in progress in Europe[3], Canada[4], and the US[5] on how to recycle waste, grow food, and regenerate air in a closed system with only energy as input. Picture a smallish, sealed building with a few windows, running solely off solar panels on the roof, thus approximating the energetics of a space station.

It's important to note that such a system, even with perfect recycling efficiency, will not last indefinitely but will be limited by the wear and tear on the mechanical components of the system. This is an engineering problem of mean time to failure which can be calculated ahead.

Once sufficiently refined, this setup would be reproduced in Low-Earth Orbit (LEO), where the additional challenges of confined space, microgravity (or artificial gravity), micro-meteorites, radiation, repairs, and spares have to be dealt with. Eventually, such a station could function for years without resupply.

Having thus no need to hurry, the station can move itself using some of the many forms of high-efficiency, low-thrust electrical propulsion, one example of which is the ion thruster[6]. In a pinch, resistojet thrusters (which work by electrically heating a fluid) can use a wide variety of propellants, but at a much lower specific impulse.

At that point, the only limitations to the location of such a station are available propellant, solar power, and calculated time until a resupply is required.

A Mars mission is a mere afterthought given this. The main factor would be a need for about 2.25 times more solar panel area to take into account the relatively reduced level of solar radiation at Mars orbit. Illumination decreases as a function of the square of the distance, so doubling the distance from the source (in this case, the Sun) divides the available energy by four. Mars is approximately 1.5 times further away from the Sun than is the Earth. This means that solar illumination on Mars is reduced to about 44% of Earth levels, hence requiring a little over twice as much receiving area in order to obtain the same amount of energy.

A bonus of such an approach is that most of the problems involved in establishing permanent bases on moons, planets, or asteroids will have already been solved. It would then actually be *easier* to establish a fixed base given solid ground and gravity.

The only limitations to the location of the station are available propellant, solar power, and calculated time until a resupply is required.

However, there is a caveat about such a system: it can never launch or land. The volume required for the life support system will make it too large and too heavy. The large quantity of solar panels will make it too fragile. Finally, a large fraction of the total energetic cost of a mission is the entry into and exit out of a planet's gravity, which exceeds the energy available in this case. For the same energetic reasons, such a station would have to be built in LEO and then "launched".

Thus, if more than fly-by missions are desired, such a traveling station will have to either be reached via a planet-side rocket, or itself be equipped with one or more small spaceships which would do a slow entry into atmosphere and then launch back to the station using a system not unlike *SpaceshipOne*. The main difference would be that such a ship would have to be able to reach the orbital velocity of the station[7]. This ship has to be a conventional high-thrust rocket system which cannot be regenerated by the station, but whose propellant must be resupplied externally.

As a consequence of this focus on low-energy space exploration, the Space Shuttle (or a similar replacement vehicle) is no longer a sensible choice. The Shuttle can lift up to 28,800 kg of cargo to LEO, sustain a crew of 5 to 10 (typically 7) for about two weeks, and function as a platform for experiments and Extra-Vehicular Activity (EVA) such as satellite repairs. It amounts to launching and landing a small space station for each mission, with the resultant extremely high maintenance requirements and propellant costs.

Experiments should be done on a permanently space-borne platform, such as the ISS, where the most efficient choice is to launch supplies and crew via cheap, reliable, single-use rockets like the Soyuz and Proton launchers. These each have a track record of hundreds of successful launches. Part of those supplies would have to include an Apollo-like re-entry capsule for returning crew and objects until the aforementioned small, light reusable system becomes possible.

Without the Shuttle, performing repairs to existing satellites would be best done by launching the required parts to the station or to an orbit close to that of the satellite, which would then be reached

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Don't Kill the Starry Messenger

Robbie Henderson
Waterloo Space Society

We all know of the great Italian mathematician and astronomer Galileo Galilei; that he was the one who discovered the four largest moons of Jupiter, the one who opposed the Church's unwillingness to accept scientific fact. But how many of us know how he actually did it? Was it intuition? How did he construct his telescopes? What did the Church have to say about it? What of his fellow colleagues? In the story that follows I will highlight a few of the more important points and events of this great astronomical era, which come mostly from Galileo's very own book, *Sidereus Nuncius*. I hope that it will give you some insight into this development of early astronomy.

The year of 1609 would be the start of Galileo's most notable accomplishments. It came to his attention that a Dutchman had made a "spyglass" with the ability to magnify distant objects. In an excerpt from his book *Sidereus Nuncius* ("The Sidereal Messenger"), he writes about this miraculous device:

About 10 months ago a rumor came to our ears that a spyglass had been made by a certain Dutchman by means of which visible objects, although far from the eye of the observer, were distinctly perceived as though nearby. About this truly wonderful effect some accounts were spread abroad, to which some gave credence while others denied them. The rumor was confirmed to me a few days later by a letter from Paris from the noble Frenchman Jacques Badovere.

It is clear that this new device fascinated Galileo. Being the clever individual that he was, he constructed his own version of this spyglass to be more powerful than those made by the Dutch glassmaker. Incidentally, he never actually saw the spyglass for himself, but used a detailed description and his own knowledge of lens-making to design them. Galileo continues:

This finally caused me to apply myself totally to investigating the principles and figuring out the means by which I might arrive at the invention of a similar instrument, which I achieved shortly afterward on the basis of the science of refraction.

> ***"I saw objects satisfactorily large and close. Indeed, they appeared three times closer and nine times larger than when observed with natural vision only."***

Astonishing, isn't it, that having been presented with this previously unheard of instrument, Galileo was able to construct and improve upon its abilities on his own? As such, it is worthwhile to show here Galileo's continuation of this discussion as it provides great insight into how he began his revolutionary discoveries.

And first I prepared a lead tube in whose ends I fitted two glasses, both plane on one side while the other side of one was spherically convex and of the other concave. Then, applying my eye to the concave glass, I saw objects satisfactorily large and close. Indeed, they appeared three times closer and nine times larger than when observed with natural vision only. Afterward I made another more perfect one for myself that showed objects more than sixty times larger. Finally, sparing no labour or expense, I progressed so far that I constructed for myself an instrument so excellent that things seen through it appear about a thousand times larger and more than thirty times closer than when observed with the natural faculty only.

...

But having dismissed earthly things, I applied myself to explorations of the heavens. And first I looked at the Moon from so close that it was scarcely two terrestrial diameters distant. Next, with incredible delight I frequently observed the stars...

This would mark the beginning to Galileo's observational achievements. He gazed at the skies and painstakingly drew reproductions of his observations. He went on to publish *Sidereus Nuncius*, which was an account of his astronomical discoveries.

Now that we have presented a brief background on Galileo's motivation, let's turn to a few of his actual discoveries. There were four major new findings that Galileo made with his telescope, which he published in his book. The first, and most notable, were the four large moons of Jupiter called Callisto, Ganymede, Europa and Io. With his telescope, he was able to detect these satellites and track them day after day. The periods of these moons were on the order of days, which told Galileo that they must be orbiting the planet Jupiter, and not the Sun alone. These four moons are now collectively called the Galilean Satellites, in honour of his discovery.

Another finding was that the planet Venus goes through phases, just like the Moon. Galileo was able to discern the waxing and waning of the sunlight reflecting off Venus, being close enough to the Earth for his telescope. This was proof that *not all planets orbited the Earth* as was once thought, and that Venus was closer to the Sun than the Earth; for if it were further away it would appear fully illuminated all the time.

A third discovery was that the Sun is dotted with dark spots on its surface. A cool experiment you can try is to direct at the Sun a telescope and projecting its eyepiece onto a sheet of white paper about a meter away from it (do *not* try looking at the Sun through the eyepiece!). An image of the Sun will appear with these "sunspots" appearing and disappearing slowly. This finding implied that the Sun was not perfect as all of the heavenly spherical bodies were believed to be, which was something the Church did not take nicely. Further, Galileo observed that these sunspots move across the Sun's surface, suggesting that it too was a rotating body.

The final major discovery by Galileo were the surface features of the Moon. Through his telescope he was able to see imperfections in the Moon. According to the Ptolemaic view of the universe, the Moon and all other heavenly bodies were perfectly spherical and smooth. As Galileo points out below, this is not the case.

...we have been led to the conclusion that we certainly see the surface of the Moon to be not smooth, even, and perfectly spherical, as the great crowd of philosophers have believed about this and other heavenly bodies, but, on the contrary, to be uneven, rough, and crowded with depressions and bulges.

He drew strikingly detailed images of the Moon from his observations.

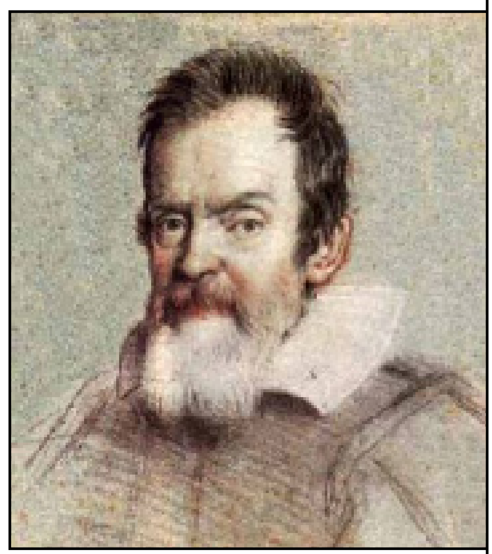
The publication of *Sidereus Nuncius* made Galileo a nearly overnight celebrity throughout Europe. News spread quickly that he, the mathematician at the University of Padua in Italy, had made many astonishing discoveries. The reception was mixed, with some of the more learned individuals delighted that there was new hard evidence for the support, although not final proof, of the Copernican theory. Others were offended that Galileo could present a work so opposing to the Church. Johannes Kepler, for example, was a great supporter to Galileo, and after reading his book wrote a lengthy letter to him. In a passage from his letter we see this quite markedly:

I may perhaps seem rash in accepting your claims so readily with no support of my own experience. But why should I not believe a most learned mathematician, whose very style attests the soundness of his judgment? He has no intention of practicing deception in a bid for vulgar publicity, nor does he pretend to have seen what he has not seen. Because he loves the truth, he does not hesitate to oppose even the most familiar opinions, and to bear the jeers of the crowd with equanimity.

"Because he loves the truth, he does not hesitate to oppose even the most familiar opinions, and to bear the jeers of the crowd with equanimity."

Of course there was also opposition to Galileo. After he paid a visit to astronomer Giovanni Antonio Magini to allow him to see for himself the four moons of Jupiter, an intensely jealous associate of Magini, Martin Horky, wrote a letter to Kepler claiming that Galileo's spyglass was nothing more than a deceiving instrument, and that the four moons were "fictitious" (see van Helden, 1989, pp. 92-93 for a discussion). Nevertheless, Galileo's claims made him the most famous and influential scientist in all of Europe. However, this power would not be able to protect him from what was to come.

Galileo attempted to publish a follow-up book called *A Dialogue on the Two Chief World Systems* but was refused, and the Church officially declared the Copernican theory blasphemous. The book was eventually published in Florence, however. Galileo was also charged with disobeying a Church order that forbade him from



mentioning the Copernican theory, among other things. Eventually, Galileo had no choice but to yield to the Church in light of his now public humiliation and persecution threats. He was placed under house arrest in Arcetri in 1633, where he died in 1642. Had Galileo challenged the Church he would almost certainly had been more dishonoured than he was. However, it is doubtful that any dishonour to Galileo survived our modern days.

I encourage you to read Galileo's book, *The Sidereal Messenger*. It is a

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Weightless on the Vomit Comet

Saadia Hussain
Waterloo Space Society

Benjamin Sanders, a third year student of Electrical and Computer Engineering at the University of Waterloo, is one of the founding members of the Waterloo Space Society. One of Ben's co-op jobs has been helping to build and test an extension to the Canadarm at MDA (formerly MD Robotics). But that is just scratching the surface of how passionate he is about space and everything related to it. It's not hard to guess that it is Ben's dream to be an astronaut.

Ben is one of the four people forming the only Canadian team that took part in the Eighth Annual Student Parabolic Flight program of the European Space Agency in Bordeaux, France, July 2005. The other three members of Ben's team are Farron Blanc of Queens University, Meghan Grant from McGill and Jeeshan Chowdhury of the University of Alberta. For two weeks in July, the team that includes two medical students conducted experiments to investigate the effect of varying gravitational pull on the human vision. All these experiments were conducted in zero gravity on the "Vomit Comet".

The weightless condition of zero gravity is created when a modified Airbus A300 goes into a 9000 feet nosedive when the engines are switched off after climbing to the arc of the parabola. During the nosedive, the plane's passengers experience 20 seconds of zero gravity which allows them to literally float all over the aircraft. The aircraft climbs up again at an angle of 45 degrees, as opposed to the commonly operated angle of 15 degrees, resulting in passengers experiencing up to 1.8 times the force of gravity on Earth. Think of that when you feel nervous during an aircraft's normal take-off! The crest and fall pattern of the plane's trajectory is shaped like a parabolic arc (like a roller coaster), thus giving the project its name. The roller-coaster pattern was repeated every 3 minutes. It is the rapid gravitational adjustments that make the passengers nauseous, thus earning the plane the notorious title of Vomit Comet.

The experiments were conducted using a hockey helmet with 90 miniature LEDs installed throughout the front and sides. The LEDs were lit one by one from the sides to the centre and as soon as the lights entered the subject's peripheral vision, the angle was recorded precisely. Our Canadian sense of pride came from this group being the only Canadian team participating in the project. Dr. Dave Williams was the team's mentor. Even better, the helmet was worn by Jarome Iginla, captain of Calgary Flames, in last year's Stanley Cup play-offs.

The team gathered enough data and

is currently in the process of analyzing the data. The findings were presented in October at the 56th International Astronautical Congress (IAC) in Japan.

For Benjamin Sanders, floating in zero gravity is more than just an accomplishment on his road to be an astronaut. In Ben's words, it is about finding one's passion in life and pursuing it fully. "I may only ever get to float just this once, but I can find passion in everyday life." Ben observes.

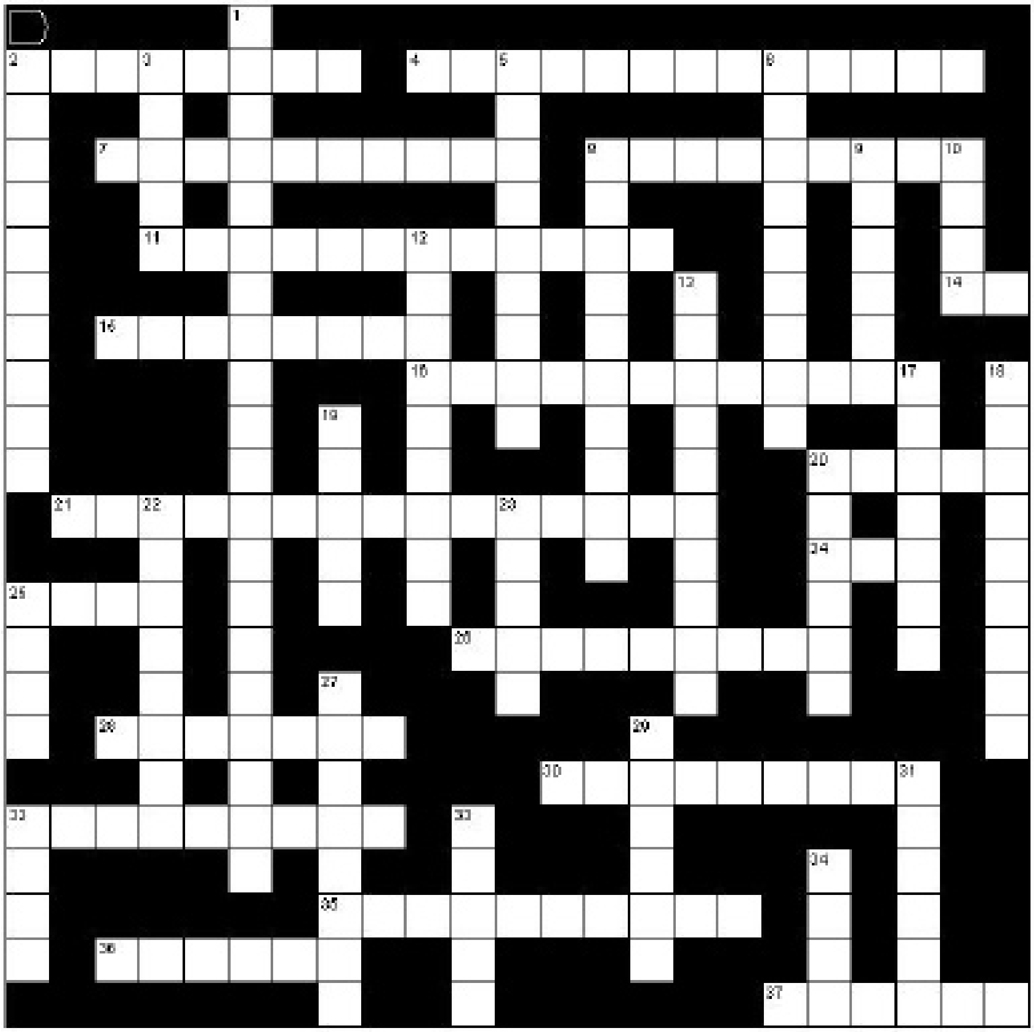
Ad Astra.

(Right) Jeeshan Chowdhury and Ben Sanders

More to explore

Celestial Crossword

Brian Koiter
Waterloo Space Society



Across

2. Small rocky body, generally found in orbit between Mars and Jupiter
4. The most luminous physical phenomenon known in the universe
7. Tiny grains found in space throughout the universe
8. The point of closest approach of a celestial body orbiting another
11. Best-known and brightest comet
14. Moon of Jupiter
15. Our sun is expected to become one of these in about 6 billion years
16. A type of spectral line
20. The odd planet out
21. Nearby dwarf galaxy
24. Seyferts, quasars and blazars are types of these
25. Earth has an oddly large one of these
26. A relatively small extra-terrestrial body that reaches the Earth's surface
28. Furthest gas giant from the sun
30. The difference between the current local sidereal time and the right ascension of an object
32. Stellar explosion
35. Venus, Uranus and Pluto have this type of rotation
36. Distant gas giant
37. Massive gravitationally bound system of stars and dust

Down

1. Einstein's "greatest blunder"
2. Slight apparent shift of a celestial object as seen from earth is caused by this phenomenon
3. A moment in time for which celestial coordinates or orbital elements are specified
5. A relatively small (sand- to boulder-sized) fragment of debris in the solar system
6. A region of space from which nothing can return
8. Wobble of the earth
9. Most stunning planet to see through a telescope
10. Organization looking for life throughout the universe
12. Anything orbiting another body
13. Large celestial body somewhere between a large planet and a small star
17. The two occasions each year when the day and the night are of equal duration
18. A star before it begins fusion
19. Portion of a moon or planet as seen from earth
20. It is difficult to see these around distant stars
22. Moon of Jupiter
23. An icy body that occasionally passes through the inner solar system
25. Most Earth-like planet known
27. The whole spacetime continuum in which we exist
29. Quasi-stellar radio source
31. Moon of Jupiter
32. Most common source of light in the universe
33. The only known habitable planet
34. Part of the tail of a comet, produced by vapor boiled off the comet as it nears the sun

Space Calendar

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Room 2053, Wilson Hall
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November 11-12

CSS Annual Space Summit
Hosted by: The Canadian Space Society
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The Space Summit brings together the best and brightest minds from both industry and advocacy to discuss the direction of the Canadian space industry and how we can help move Canadian space endeavours forward. Hosted in cooperation with CSS member organisations, the year's Space Summit will continue its growth towards being the Canadian industry/advocacy event of the year.

Monday, November 21

CSS monthly meeting.

Tuesday, December 13

CSS monthly meeting. Annual Dinner & Roundtable.

Monday, November 21

CSS monthly meeting.

Monday, January 16

CSS Annual General Meeting.

Tuesday, February 21

CSS monthly meeting.

Monday, March 20

CSS monthly meeting.

Tuesday, April 18

CSS monthly meeting.

Want to know how to get your event listed here and through other CSS announcement listings? Contact the editor at editor@css.ca.

TERRAPIN STATION
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using the station's small ship as a mobile base to perform the repairs from.

More so than the development of expedition-style missions, the refinement of self-sustaining space habitation has direct applications on Earth. The same engineering would make it feasible to inhabit previously difficult locations such as the deep desert, the tundra, or other places where waste management and power infrastructure cannot be brought out for engineering or economic reasons. Even within cities, the same technologies could reduce the extent and cost of those utilities.

While by no means a fast-track to space exploration this slow-and-steady approach, like that of the proverbial turtle, would make our next step into space a very solid, sustained, and economical one.

[1] **The Annotated Terrapin Station**
http://arts.ucsc.edu/gdead/agdl/terr.html
[2] **Biosphere-3** aka BIOS-3
http://en.wikipedia.org/wiki/BIOS-3
[3] **Micro-Ecological Life Support System Alternative** aka MELiSSA
http://www.estec.esa.nl/ecls/?p=melissa
[4] **Controlled Environment Systems Research Facility**
http://www.ces.uoguelph.ca
[5] **Advanced Life Support**
http://advlifesupport.jsc.nasa.gov
[6] **Ion Thruster**
http://en.wikipedia.org/wiki/Ion_thruster
[7] **Difference between sub-orbital and orbital spaceflights**
http://en.wikipedia.org/wiki/Difference_between_sub-orbital_and_orbital_spaceflights

STARRY MESSENGER
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fascinating and insightful account of early astronomical development. There are also a vast number of books written on historical astronomy, a few of which I point out below. As a final note, I would like to leave you with a most interesting passage written by Kepler to Galileo on his discovery of Jupiter's satellites:

The conclusion is quite clear. Our moon exists for us on the Earth, not for the other globes. Those four little moons exist for Jupiter, not for us. Each planet in turn, together with its occupants, is served by its own satellites. From this line of reason we deduce with the highest degree of probability that Jupiter is inhabited.

Kepler always did have a knack for imaginative writing, from time to time.

Robbie Henderson is a third year Honours Mathematical Physics student at the University of Waterloo. Contact Robbie at rdehende@scimail.uwaterloo.ca

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